-A086 289 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 21/3
DEVELOPMENT OF A 30,000-AMPERE REVERSING CONTACTOR.(U)
MAY 80 D B STEEN
UNCLASSIFIED DTNSRDC/PAS-79/40 NL

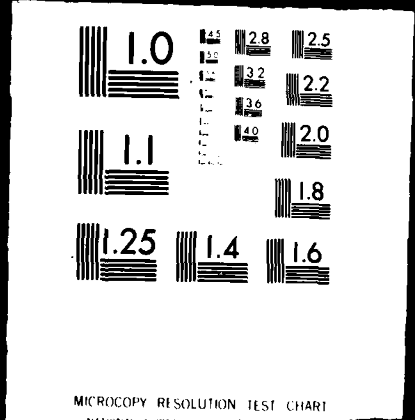
1 OF 2
AD
A086289

END
DATE
FILMED
8 80
DTIC

CONT.

1 OF 2

AD A086289



LEVEL II

(12)

DTNSRDC/PAS-79/40

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

ADA086289

DEVELOPMENT OF A 30,000-AMPERE REVERSING CONTACTOR

by

D. B. Steen

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

PROPULSION AND AUXILIARY SYSTEMS DEPARTMENT

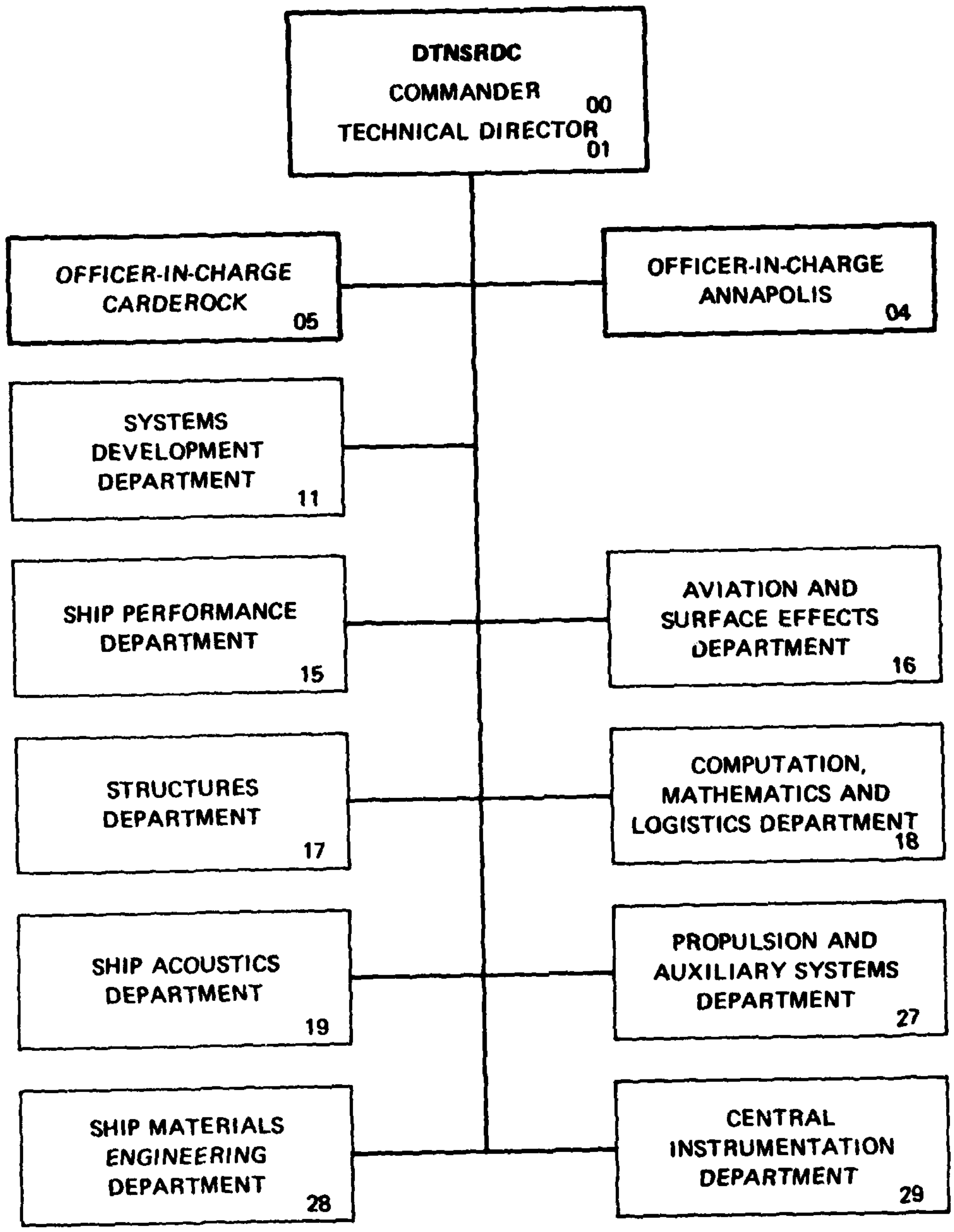
RESEARCH AND DEVELOPMENT REPORT

May 1980

DTNSRDC/PAS-79/40

DEVELOPMENT OF A 30,000-AMPERE REVERSING CONTACTOR

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: (14) DTNSRDC/PAS-79/40
2. GOVT ACCESSION NO.: AD-A086289
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): (6) DEVELOPMENT OF A 30,000-AMPERE REVERSING CONTACTOR
5. TYPE OF REPORT & PERIOD COVERED: (9) Final Report
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): (10) Donald B. Steen
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: David W. Taylor Naval Ship R&D Center, Bethesda, Maryland 20084
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: (See reverse side)
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Sea Systems Command (SEA 05R), Washington, D. C. 20362
12. REPORT DATE: (11) May 1980
13. NUMBER OF PAGES: 36
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 37
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report):

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

(16) S0380

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): (17) S0380SL
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

Switchgear
Switch Contacts
High Current

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the design and construction of a double-pole double-throw 30,000-ampere contactor for use in a 400-horsepower experimental propulsion system. The contactor is designed to reverse the polarity of the input current to the motor for motor reversal. The contactor consists of two opposed contact assemblies, each assembly consisting of vie contact plates which are connected by bus bars to the generator and motor terminals. A motor-driven shuttle slides between the contact assemblies to electrically → over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED 408615 JB

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 10)

Task Area 16761
Project S0380-SL
Project Element 63058N
Work Unit 2722-100

(Block 20 continued)

connect pairs of contact plates together to form a double-pole, double-throw center-off configuration. The size of the contactor, exclusive of the drive motor, is 0.533 x 0.406 x 0.139 meter. At 30,000 amperes, contactor losses are less than 2000 watts. The small size and low insertion loss of the contactor is primarily due to an unique multilouvered contact strip which is inserted into slots milled into the surface of the shuttle. These contact strips are rated by the manufacturer for a continuous current density of 466 amperes per square inch. The small size and low loss of this contactor compare favorably with contactors of similar current ratings presently available. Preliminary tests have shown that the contactor meets or exceeds the design specifications and that its characteristics are better than those predicted.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

LIST OF ABBREVIATIONS

A	Ampere
cm	Centimeter
DC	Direct current
DPDT	Double-pole, double-throw
hp	Horsepower
in	Inch
kg	Kilogram
lb	Pound
m	Meter
N	Newton
°C	Degrees Celsius
OFHC	Oxygen-Free High-Conductivity
SPST	Single-pole, single-throw

ABSTRACT

This report describes the design and construction of a double-pole, double-throw 30,000-ampere contactor for use in a 400-horsepower experimental electric propulsion system. The contactor consists of two opposed contact assemblies, each assembly consisting of five contact plates which are connected by bus bars to the generator and motor terminals. A motor-driven shuttle slides between the contact assemblies to electrically connect pairs of contact plates together to form a double-pole, double-throw, center-off configuration. The size of the contactor, exclusive of the drive motor, is 0.533 X 0.406 X 0.139 meter. At 30,000 amperes, contactor losses are less than 2000 watts. The small size and low insertion loss of the contactor is primarily due to an unique multilouvered contact strip which is inserted into slots milled into the surface of the shuttle. These contact strips are rated by the manufacturer for a continuous current density of 466 amperes per square inch. The small size and low loss of this contactor compare favorably with contactors of similar current ratings presently available. Preliminary tests have shown that the contactor meets or exceeds the design specifications and that its characteristics are better than those predicted.

ADMINISTRATIVE INFORMATION

This report is based on work performed under DTNSRDC Work Unit 2722-100 as part of the supporting technology for the NAVSEA Superconductive Propulsion Project, Task 16761, Project S0380-SL, Element 63058N. The program manager is NAVSEA (SEA 05R11).

The design and analysis work described herein was performed and documented in a draft report in 1976. Although the draft report was not processed until 1979, the design philosophy and data remain valid.

INTRODUCTION

As part of NAVSEA Project S0380-SL, the Navy is developing electrical propulsion systems which utilize acyclic motors and generators having super-conductive field windings. The high-current, low-voltage characteristics of acyclic machines and the inability to quickly reverse superconductive fields have made the development of low-loss, high current switchgear a necessary part of the program. Systems under development, or under consideration, range from a 30-volt, 24,000-ampere system employing a single motor and generator to systems using

motors and generators operating at voltages greater than 300 volts and currents up to 100,000 amperes. Investigations[1]* have shown that the highest direct-current switch available is a water cooled unit rated at 20,000 amperes. Switchgear manufacturers have historically produced high-current switches by ganging together a sufficient number of lower-current switches to provide the required current capacity. For reliable operation, not more than ten switches are usually ganged together. Instead of taking the historical approach, DTNSRDC studied the feasibility of constructing a single switch rated at 30,000 amperes which could be easily modified for higher currents by increasing its dimensions. A liquid-metal switch was designed and constructed as a result of this feasibility study. While the construction of this liquid metal switch was progressing, a new type of contact material became available in the United States[2] which appears to have great promise in future switchgear designs. This multilouvered contact material is suitable for both fixed and moving contact systems and can be employed in flat, cylindrical, and polygonal contact assemblies. The louvers in the contact strips are formed to provide their own contact pressure when inserted into slots of the proper depth. By eliminating the necessity of using liquid metal with its involved handling, sealing, and clean-up procedures, switchgear using this multilouvered contact material appear to be superior to liquid-metal switchgear for shipboard applications. This report describes the characteristics and detail design of a 30,000-ampere DPDT** switch employing this multilouvered contact material.

CONCEPTUAL DESIGN AND ANALYSIS

Theory states that two surfaces, when in contact with each other under light pressure, will contact each other at not more than three points. Additional points of contact can be obtained only by increasing the contact pressure. The physical problem of creating an electrical contact between two surfaces, without using liquid metal as the contact interface, has been approached by two different methods:

1. Apply large forces to the contacts to cause the high spots of one contact to extrude or to form depressions in the other contact so that many points may be allowed to contact.

2. Divide one contact member into a number of flexible sections and apply sufficient forces so that each section comes in contact with the other contact member.

The first method requires the application of force to increase the

*A complete listing of references is given on page 29 .
**Definitions of abbreviations used are given on page 5.

contact area. This method, however, is a random one, and a point is quickly reached where an increase in force yields only marginal increases in contact area. There is also a practical limit to which force can be applied without permanently distorting the contact surface area. Occasionally, one of the contact surfaces is plated with a noble metal, i.e., gold or silver, to eliminate the corrosion which causes high contact resistance. More frequently, one contact surface slides across the other before the contact surfaces are put under pressure in order to wipe both surfaces free of extraneous material and to cause each surface to wear down the high spots on the other surface. Plating the surfaces and sliding the surfaces together help to reduce the amount of force needed to obtain a low resistance contact area.

The second method overcomes the large forces required by the first method, but it requires a great deal of machining to divide one surface into a sufficient number of contact fingers to ensure that each finger can carry its share of the current while remaining flexible so that it bends under relatively light pressure. Sliding the surfaces together helps to clean both surfaces and to remove the high spots. A recently developed device, the Multilam band[2], makes use of the contact finger concept and eliminates the need for sizing each contact finger for flexibility and for current carrying capacity. It is this contact strip that is the basic component of the DPDT switch.

CHARACTERISTICS OF THE MULTILAM BAND

The Multilam band is designed to provide a large contact area at low force levels. The band is made from beryllium-copper and is formed into a multitude of identical louvers. Each louver is bent into a "S" shape so that each louver acts as a current transfer means and a torsional spring. The bands are inserted into slots milled into one contact surface. When the other contact surface is pressed against the bands, the louvers are deflected enough to create contact pressure and a well-defined line of contact on the surfaces of each louver. Because the bands are available in various thicknesses and size of louvers, a large number of combinations of current versus force versus contact area can be achieved. A great number of contact arrangements are possible because the band is flexible enough that it can be used flat or formed around cylindrical contact surfaces. Each louver is a torsional spring under tension while mated, and it automatically compensates for expansion and contraction during heating cycles by rotating about its axis. The contact strip can operate continuously at a temperature of 200°C and can be silver plated to increase the durability of the contact surface. A very desirable feature of these contact strips is their ease in installation and their simple replacement whenever they become worn.

At the time the contactor described herein was being designed, there were nine primary types of louvered bands available whose character-

TABLE 1 - MULTILAM BANDS

Type	Continuous Current Rating, amperes per louver	Continuous Current Rating, amperes per cm	Band Thickness cm	Band Width cm	Current Density A/cm^2
LAO/.15	35	69	0.015	2.54	1129
LAO/.2	44	86	0.020	2.54	1419
LAO/.25	55	108	0.025	2.54	1774
LAO/.3	66	129	0.030	2.54	2129*
LAI/.15	20	79	0.015	1.80	1812
LAI/.2	28	110	0.020	1.80	2541
LAI/.25	35	137	0.025	1.80	3174
LAI/.3	42	165	0.030	1.80	3812*
LAI/.5	70	275	0.050	1.80	6354*

*Fixed contacts only.

istics are compiled in Table 1. Within each primary type, there were various options available, such as the type of plating desired, the angle at which the tabs on the edge are bent, and the radius into which the band is formed. The bands with a thickness of 0.015, 0.020 or 0.025 cm are reportedly suitable for moving contacts. Bands with greater thicknesses were recommended for use as fixed contacts because of their stiffness. The type LAO bands have two louvers per centimeter, and the Type LAI bands have four louvers per centimeter. The last column of Table 1 shows the average current density in the contact area covered by the band. The band that was selected for the DPDT switch was Type LAI/.25 because of its high-current density. The band was obtained as a flat strip, silver plated, and with the tabs not bent. Specific characteristics of the selected band are shown in Figure 1.

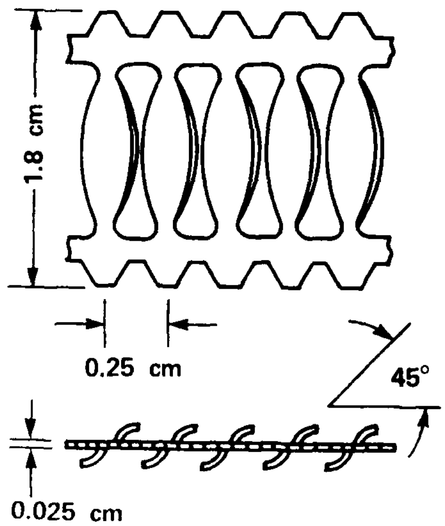
The louvered band is made from a strip of beryllium-copper, 1.77 cm wide and 0.025 cm thick. Each louver is formed into an "S" shape and twisted about its longitudinal axis through an angle of approximately 45 degrees. The louvered strip thus formed is hardened, passivated, and electroplated with silver. The cross-sectional area available for current transfer in each louver varies from 0.013 to 0.019 cm^2, depending on the contact pressure. The current density within the louver is between 7.74 and 10.96 A/m^2. The heat generated in each louver at the rated current of 35 amperes is only 0.06 watt, an amount of heat easily conducted through the electrical contact, as will be shown in a later section of this report.

Figure 2 shows the typical electrical current capacity and force required on each louver as functions of the louver deflection as reported by the manufacturer[2]. For small louver deflections, the current capacity quickly reaches its maximum value and essentially maintains this value for all greater deflections. At the maximum recommended deflection, the louver begins to flatten out and permanently deform from its original shape. The design point that was selected for the switch was at a deflection that was approximately one-third of the maximum recommended deflection to allow for contact surface roughness and wear. This point was at a current of 35 amperes, a louver force of 0.181 kg, and a deflection of 0.033 cm. This deflection gives a contact spacing of 0.0939 cm, as shown in Figure 1.

CONCEPTUAL SWITCH DESIGN

The arrangement and switch positions of the DPDT switch are depicted in Figure 3. The switch is constructed of two assemblies of copper contacts, separated by slabs of electrical insulation. A shuttle with Multilam strips inserted in grooves milled in the surface moves between the assemblies to selectively connect cables from the motor and generator terminals together through external bus bars, as are the two "Motor +" conductors at each end of the switch. In the forward

DIMENSIONS



SPECIFICATIONS

CURRENT PER LOUVER	
CONTINUOUS	35 A
3 SECOND	770 A
1 MILLISECOND	3500 A
VOLTAGE DROP	
NEW	0.010 V
80,000 OPERATIONS	0.016 V
CONTACT FORCE (PER LOUVER)	0.181 kg
COEFFICIENT OF FRICTION	
DRY	0.15 TO 0.18
LUBRICATED	0.10 TO 0.16

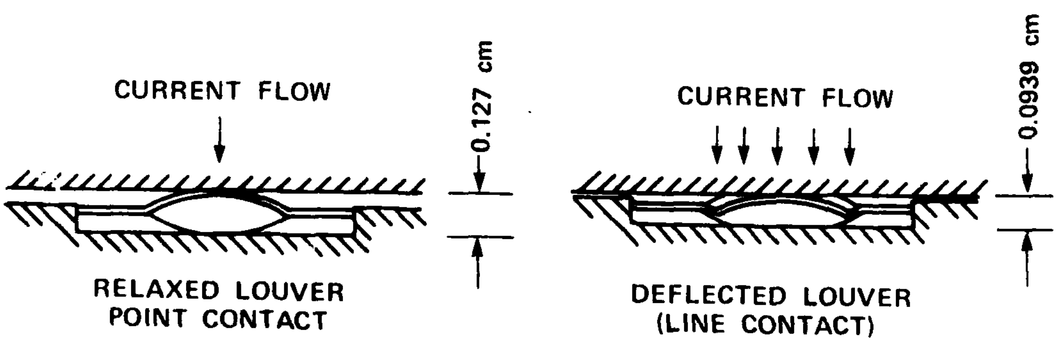


Figure 1 - Multilam Band Type LAI/.25

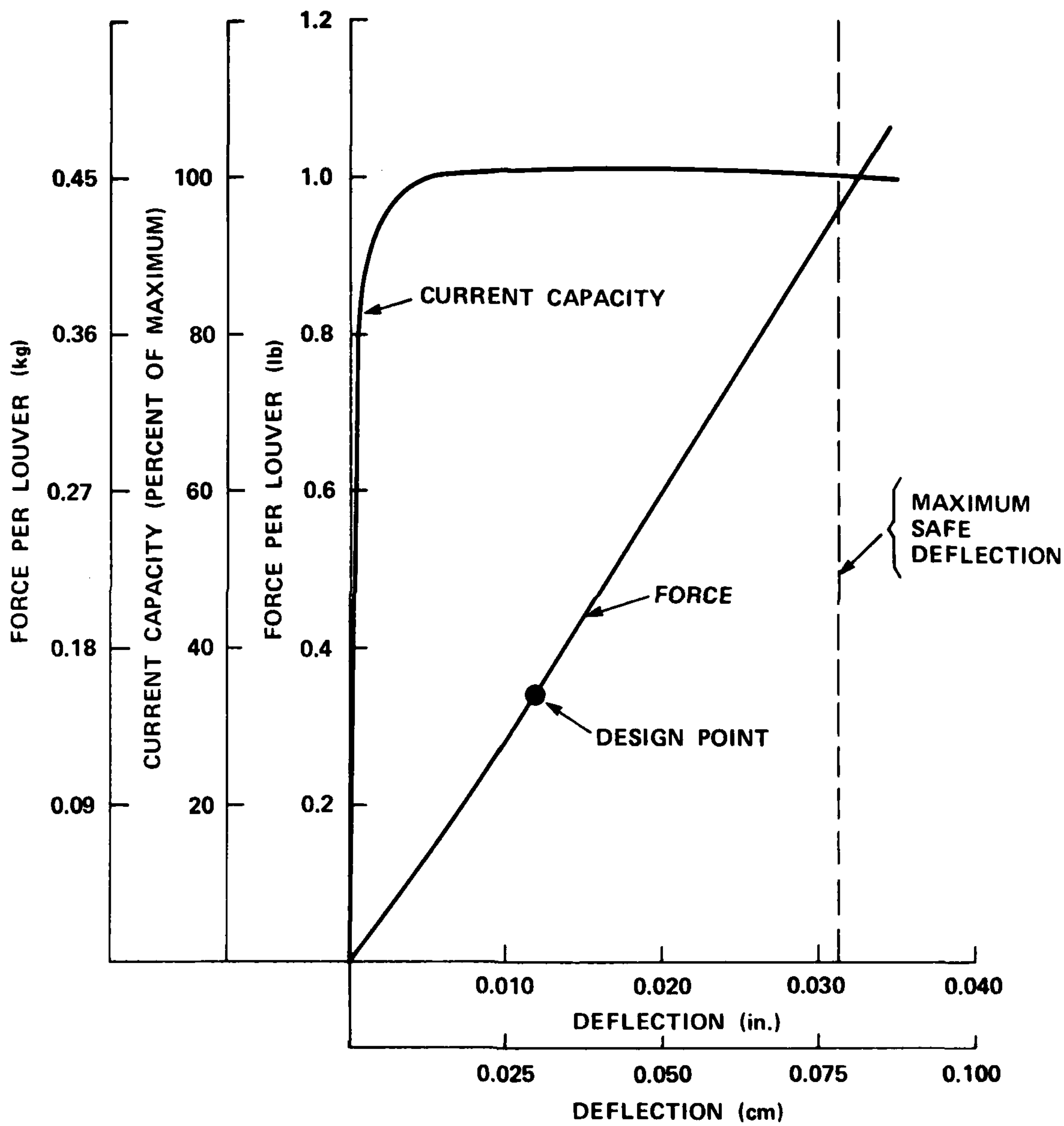


Figure 2 - Multilam Band Type LAI/.25
Typical Characteristics

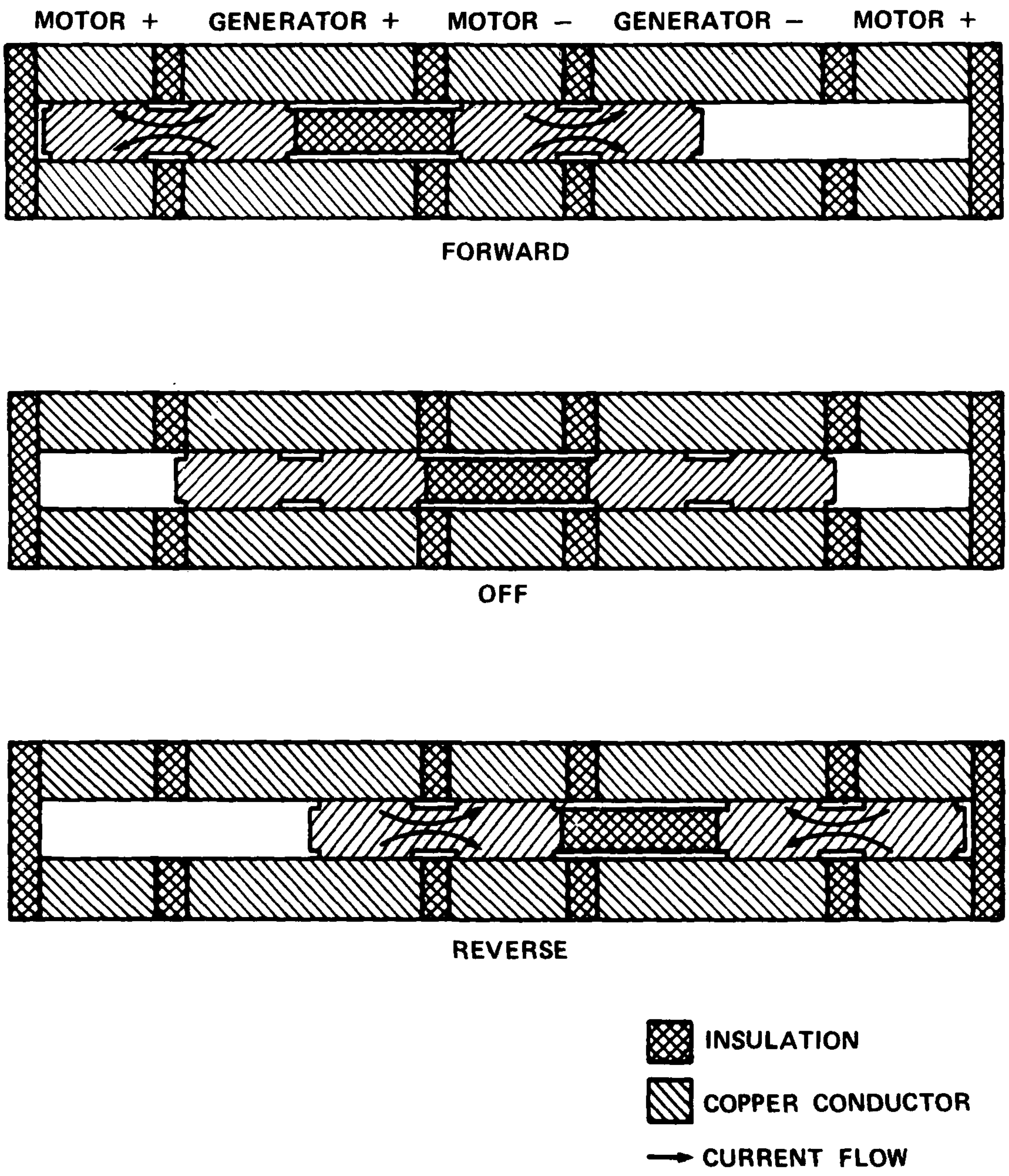


Figure 3 - DPDT Switch Positions

position, the "Motor +" and "Generator +" contacts are connected together through the left conductor of the shuttle, and the "Motor -" and "Generator -" contacts are connected together by the right conductor of the shuttle. In the off position, the shuttle slides to the center of the switch and disconnects the "Motor +" and "Motor -" contacts. In the reverse position, the left conductor of the shuttle connects the "Generator +" and "Motor -" contacts together, and the right conductor of the shuttle connects the "Generator -" and "Motor +" contacts together. In the propulsion system, the DPDT switch will be operated after the circuit to the motor and generator is opened by means of a shunt switch and rheostat as outlined by Steen[1].

SWITCH ANALYSIS

The switch analysis has consisted of determining its electrical losses, the temperature rises throughout the switch, and its mechanical and electrical characteristics. The data thus obtained will be used as reference material during final testing and evaluation of the switch for its intended use. Figure 4 shows the model used in determining the electrical losses. The model consists of a typical crosssection of the switch with a thickness of 0.1 in. (0.254 cm). The dimensions used in the model are typical of those in the switch. A current of 70 amperes is assumed to flow in each half of the switch which splits equally among two louvers. Through the shuttle, the two 70-ampere currents combine to form a 140-ampere current. The material in each half of the switch and the shuttle is OFHC copper, and the louver material is beryllium-copper. The dimensions assumed for the contacts and a louver are shown in Figure 5. A 35-ampere current flows through the louver and is uniformly distributed over a rectangular area measuring 0.01 x 0.20 in. (0.025 X 0.50 cm). Both the 2- x 2-in. and 2- x 4-in. contacts have 15,000 amperes flowing from one face at the approximate locations shown and a uniformly distributed current of 275 A/cm of length flowing into the opposite face.

The electrical losses in the switch are shown in Table 2, along with the equation used to calculate these losses. The ohmic loss in each beryllium-copper louver is calculated using the dimensions for the louver in Figure 5. The loss in the shuttle is calculated using the dimensions in Figure 4. The loss in the contact interface was estimated using the manufacturer's published data for the voltage drop in a louver in a new condition and after 80,000 operations[2]. The losses in the 2- x 2-in. and 2- x 4-in. contacts were calculated using the dimensions in Figure 5 and summing the current in the contact from each end to the point where the current leaves the contact. The equations shown do not give a precise loss for the 2- x 2-in. and 2- x 4-in. contacts, but the resulting losses are sufficiently accurate for the analysis of the swtich. Actual losses will be measured when the switch is tested, and it is anticipated that the measured losses will not be much different

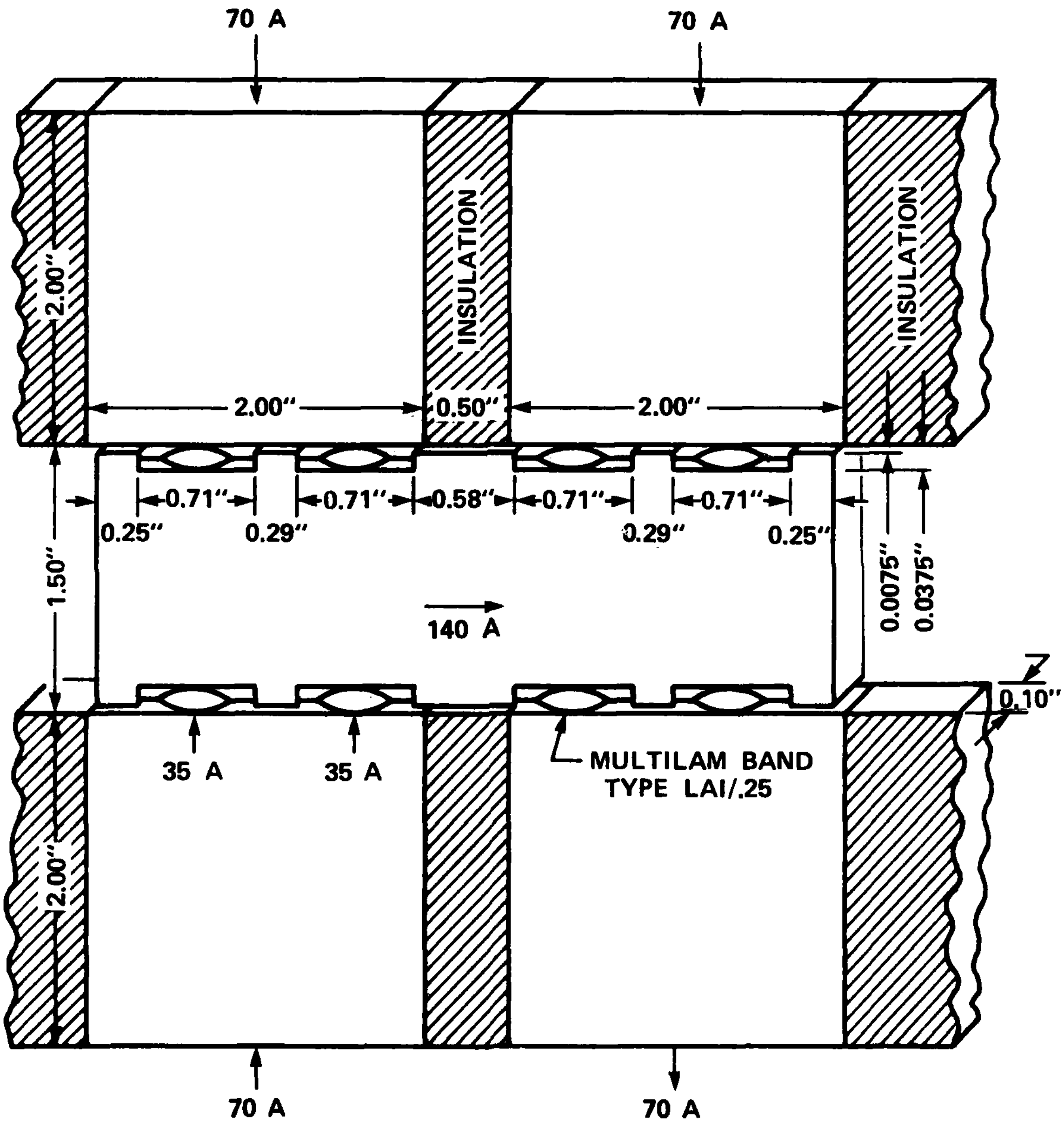


Figure 4 - Switch Analysis Model

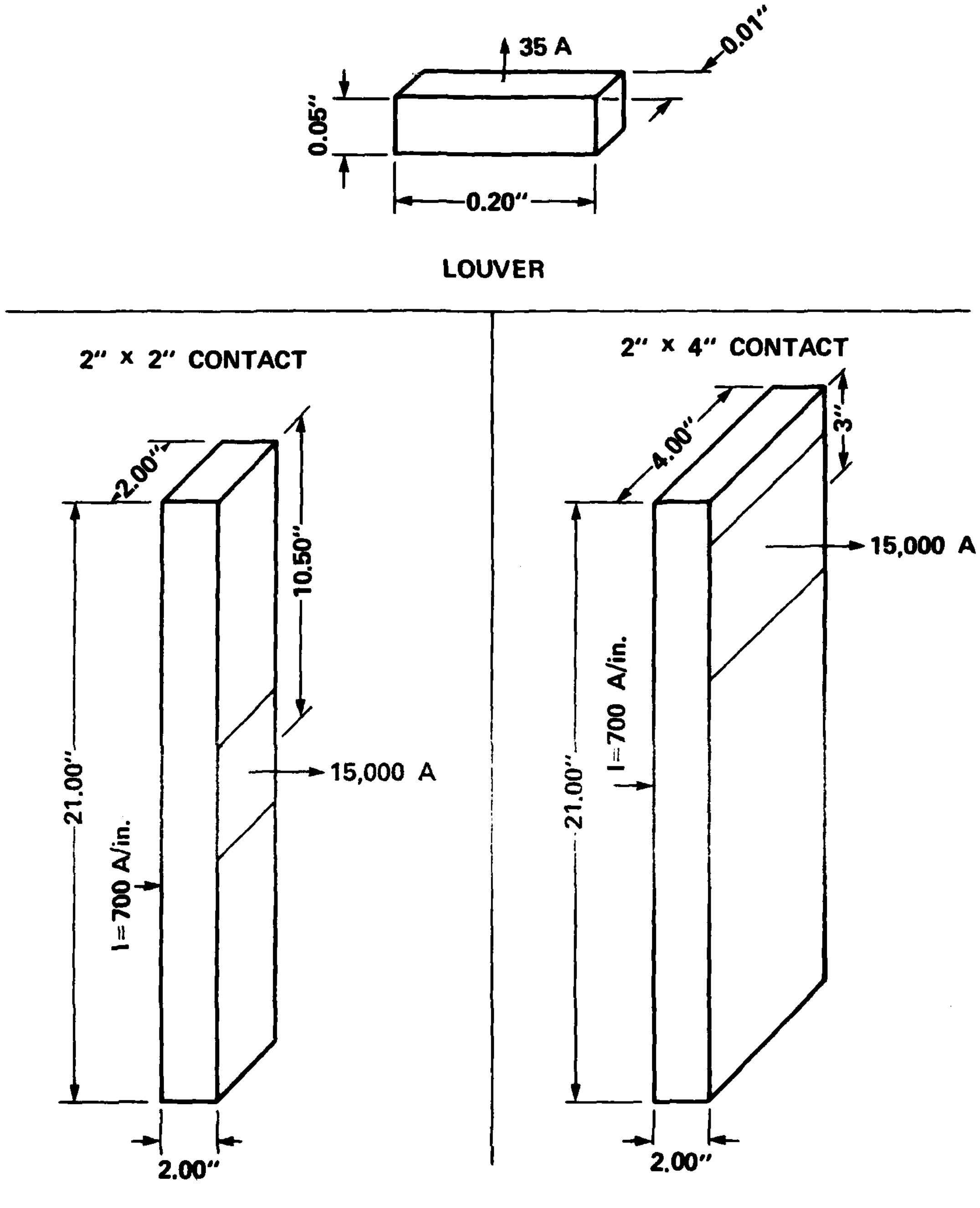


Figure 5 - Switch Analysis Details

TABLE 2 - ESTIMATED DPDT SWITCH LOSSES
AT 30,000 AMPERES

Location	Variable	Equation	Power Loss watts
Louver Material	W_M	$\frac{I^2 \rho L}{A} = \frac{(35)^2 (2.16 \times 10^{-6})(0.05)}{(0.01)(0.20)}$	0.066
Shuttle	W_S	$\frac{I^2 \rho L}{A} = \frac{(140)^2 (0.681 \times 10^{-6})(2.29)}{(0.10)(1.425)}$	0.208
Contact Interface	W_C	$\frac{V_{DROP} I - W_M}{2} = \begin{cases} \frac{(0.01)(35) - 0.066}{2} \\ \frac{(0.016)(35) - 0.066}{2} \end{cases}$	0.142 new 0.247 worn
2- x 2-in. Contact	W_A	$2 \int_0^{11.5} \frac{(1.5 \times 10^4)^2 (0.681 \times 10^{-6})\ L^2 dL}{(21)^2 (2)(2)}$	88.08
2- x 4-in. Contact	W_B	$\int_0^{3} \frac{(1.5 \times 10^4)^2 (0.681 \times 10^{-6})\ L^2 dL}{(21)^2 (2)(4)} + \int_0^{18.0} \frac{(1.5 \times 10^4)^2 (0.681 \times 10^{-6})\ L^2 dL}{(21)^2 (2)(4)}$	84.83
Total Loss	W_T	$4\ (W_A + W_B) + \frac{(\text{[illegible]} \times 10^4)(4W_M + 8W_C + W_S/2)}{35}$	1977 new 2697 worn

from those shown in Table 2. The total loss in the DPDT switch was calculated by summing the losses in each of the current carrying members and is shown for both new contacts and for contacts after 80,000 operations.

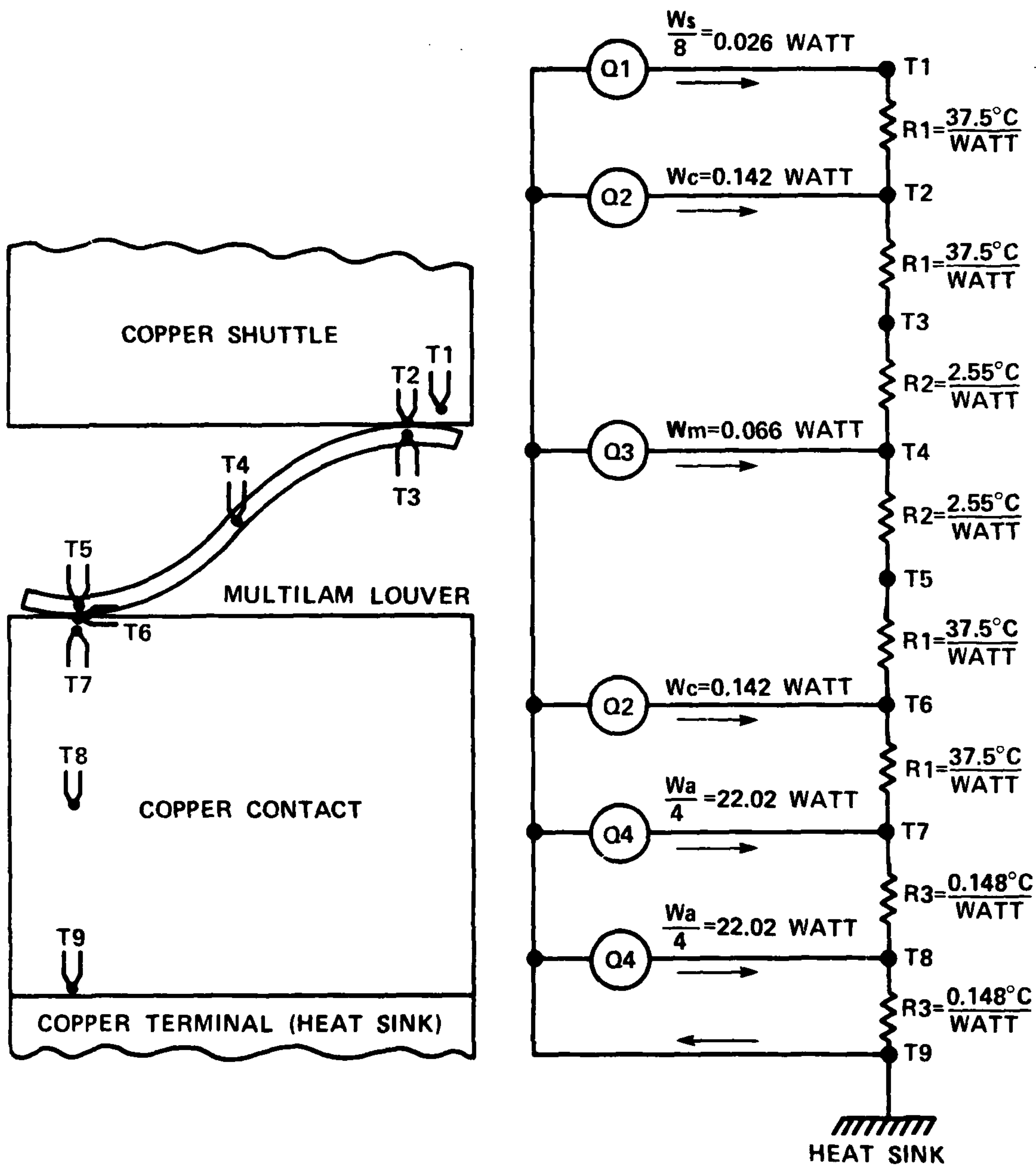
Figure 6 shows the locations of temperatures and the analog circuit used to determine the temperature rise in the switch while conducting 30,000 amperes. Nine temperatures along a typical heat flow path were calculated from the shuttle to the outer surface of the switch. The losses are represented as current sources. The thermal resistances are those of one-half of a typical pressure contact measuring 0.025 x 0.50 cm with a surface roughness of 1×10^{-5} cm obtained from a NAVSHIPS manual[3] (R1), the thermal resistance of a 0.063-cm bar of beryllium-copper with a crosssection of 0.025 x 0.5 cm (R2), and a 14-cm bar of 2- x 2-in. OFHC copper (R3). The direction of flow of current is shown by the arrows on the analog circuit.

The calculated temperature rises in the switch with new louvers and with louvers that have undergone 80,000 operations are shown in Table 3. With the outside surface of the switch maintained at 40°C by suitable cooling, the highest temperature in the switch located on the shuttle will be approximately 81°C when the louvers are new and 103°C when the louvers are worn. The louvers have a maximum temperature rating of 200°C, which is much higher than either of the calculated shuttle temperatures. There should, therefore, not be any difficulty from overtemperature in the switch at 30,000 amperes.

DRIVE MOTOR CHARACTERISTICS

The typical performance characteristics of the drive motor are shown in Figure 7. The motor is rated by the manufacturer at 1/4 hp, 1200 rpm at a current of 10 amperes. Because the motor operates intermittently, it will withstand considerable overloads and will be operated at torques of between 22 and 40 lb-in. As shown by Figure 7, these torques are well within the motor's maximum ratings of 100 lb-in. of torque and 0.8 hp. Because the motor will normally have a duty cycle of 2 sec on and and greater than 2 min off, no dange of overheating the motor should be encountered.

A condensed list of the DPDT switch characteristics appears in Table 4. The size, weight, and electrical losses are extremely small for a switch with this current rating. Obviously, the size and weight can be reduced, but at the expense of increased electrical losses. The reversing time is good when compared to switches of similar ratings. Like most other high current switches, the DPDT switch cannot open a current carrying circuit, but must be utilized as a contactor which operates after the main circuit has been opened by some other switching device.



TEMPERATURE LOCATIONS ANALOG CIRCUIT

Figure 6 - Thermal Models

TABLE 3 - TEMPERATURE RISE
IN DPDT SWITCH

Differential Temperature	Temperature Rise, °C New	Temperature Rise, °C Worn
T1 - T2	0.975	0.975
T2 - T3	6.300	10.237
T3 - T4	0.428	0.696
T4 - T5	0.596	0.864
T5 - T6	8.775	12.712
T6 - T7	14.100	21.975
T7 - T8	3.314	5.159
T8 - T9	6.567	10.234
Total Temperature Rise (T1 - T9)	41.055	62.852

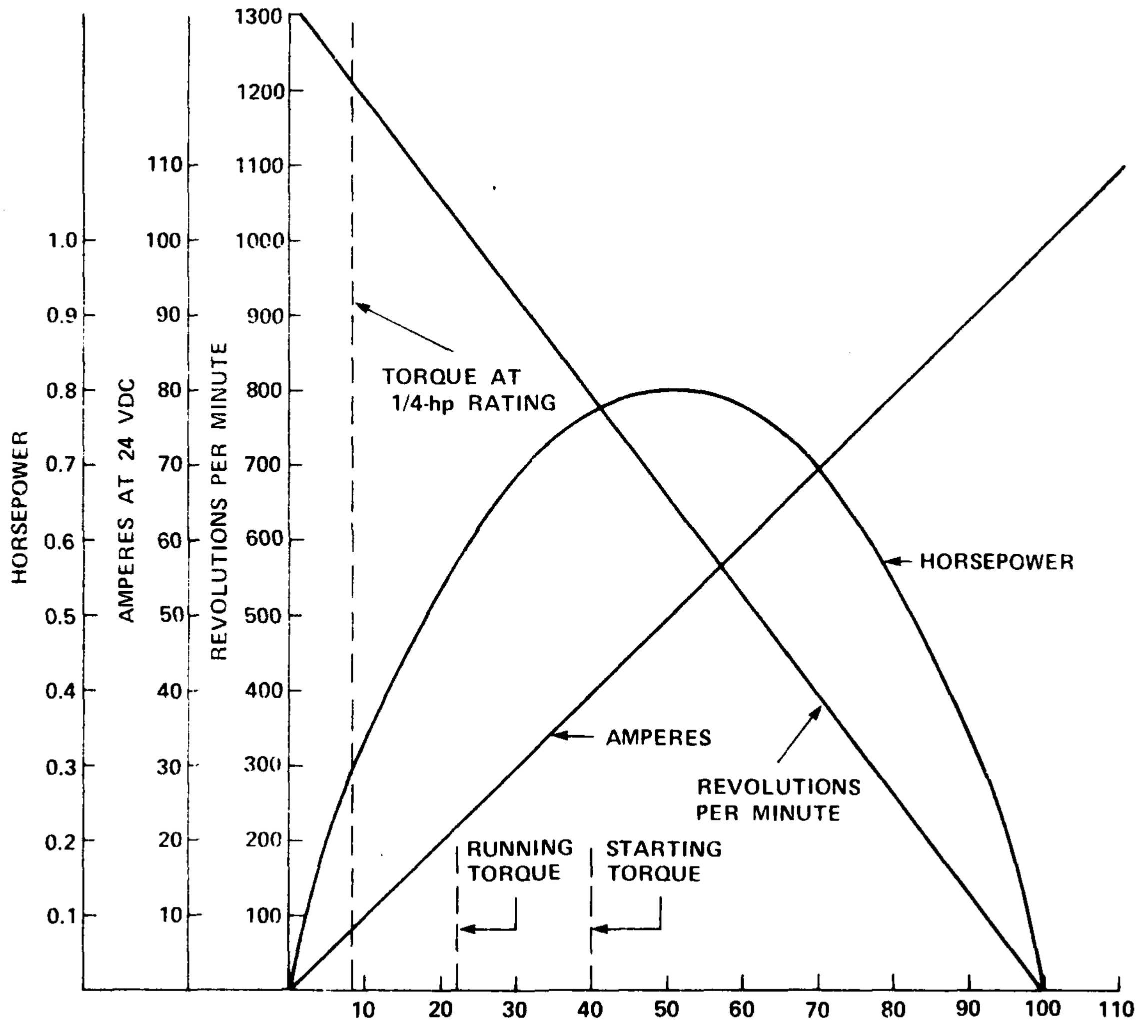


Figure 7 - 1/4-Horsepower, Permanent Magnet Direct-Current Motor Characteristics

TABLE 4 - DPDT SWITCH CHARACTERISTICS

Size, cm	
Switch	45.7 x 55.8 x 13.9
Overall (Includes Drive Mechanism)	80.6 x 60.9 x 13.9
Weight, kg	
Switch	229
Overall	237
Drive Mechanism	
Drive Motor	1/4 hp, 1200 rpm, 24 VDC, permanent magnet
Shuttle Speed, cm/sec	10
Reversing Time (forward to reverse), sec	1.125
Capacity, amperes	30,000
Current Density at 30,000 Amperes, A/m^2	
Contact Interface	0.3 (average)
Shuttle	0.645 (maximum)
Contact (2 x 2 in.)	2.41 (maximum)
Louvers	2.25 (average)
Louver Specifications	
Current per Louver, amperes	35
Current per Inch of Band, amperes	350
Thickness, cm	0.0254
Maximum Contact Speed, cm/sec	50.8
Coefficient of Friction	
Lubricated	0.10-0.16
Dry	0.15-0.18
Electrical (at 30,000 Amperes)	
Insertion Loss, watts	
New	1977
Worn (80,000 Operations)	2687
Internal Resistance, ohms	
New	2.196×10^{-6}
Worn (80,000 Operations)	2.985×10^{-6}

DETAIL DESIGN AND CONSTRUCTION

The detail drawings for constructing the DPDT switch are identified as DTNSRDC Drawings E-A-18778, Sheets 1 through 4. Reduced copies of these drawings are shown as Figures 8 through 11.

SWITCH ASSEMBLY

Figure 8 shows the general assembly of the DPDT switch. The numbers shown in parentheses in the following description refer to part numbers on the switch drawings. The front and back of the switch are constructed of bus bars (2 and 3) separated by insulation spacers (5). The bus bars and spacers are held together into a rigid assembly by threaded rods (25) which are electrically insulated from the bus bars by rigid tubing (21) and insulators (23 and 24), and fastened by nuts (27) and washers (28). End plates (1 and 4) and the top and bottom plates (6) completely enclose the switch and act as mountings for the drive motor (15) and the shuttle position sensing switches (14). An insulated bus spacer (42) holds the front and back of the swtich spaced the proper distance apart to allow clearance for the shuttle. A shuttle comprising two shuttle bus bars (7), insulators (8), and top and bottom plates (9) is held together by threaded rods (26), which are electrically insulated from the shuttle bus bars by rigid tubing (21) and insulators (23 and 24), and fastened by nuts (27) and washers (28). The drive mechanism consists of the drive motor (15), shaft coupling (16), bearings (17 and 18), and the ball bearing screw assembly (19). The drive screw is electrically insulated from the shuttle bus bars by rigid insulation tubing (22) and the shuttle lock (10). The switch brackets (13), the bearing housing (12), and the motor mounting bracket (11) complete the DPDT switch assembly. Stainless steel hardware is used to bolt the switch components together. Electrical contact between the shuttle bus bars and the terminal bus bars is by means of multilouvered contact strips (20), which are laid in the grooves in the shuttle bus bars and fastened by coining the edge of the grooves in several places with a circular punch. The position sensing switches (14) are located so that they are actuated when the shuttle reaches the forward, neutral, or reverse switch position. The positions of those switches are adjustable, and their point of actuation in relation to the shuttle position can be determined by inserting a depth gage through the holes sealed by pipe plugs (43) to measure the location of the shuttle. The entire switch is enclosed to prevent foreign material from entering the switch. The multilouvered contact strip is lubricated to reduce wear of the contact surfaces and contact sliding friction.

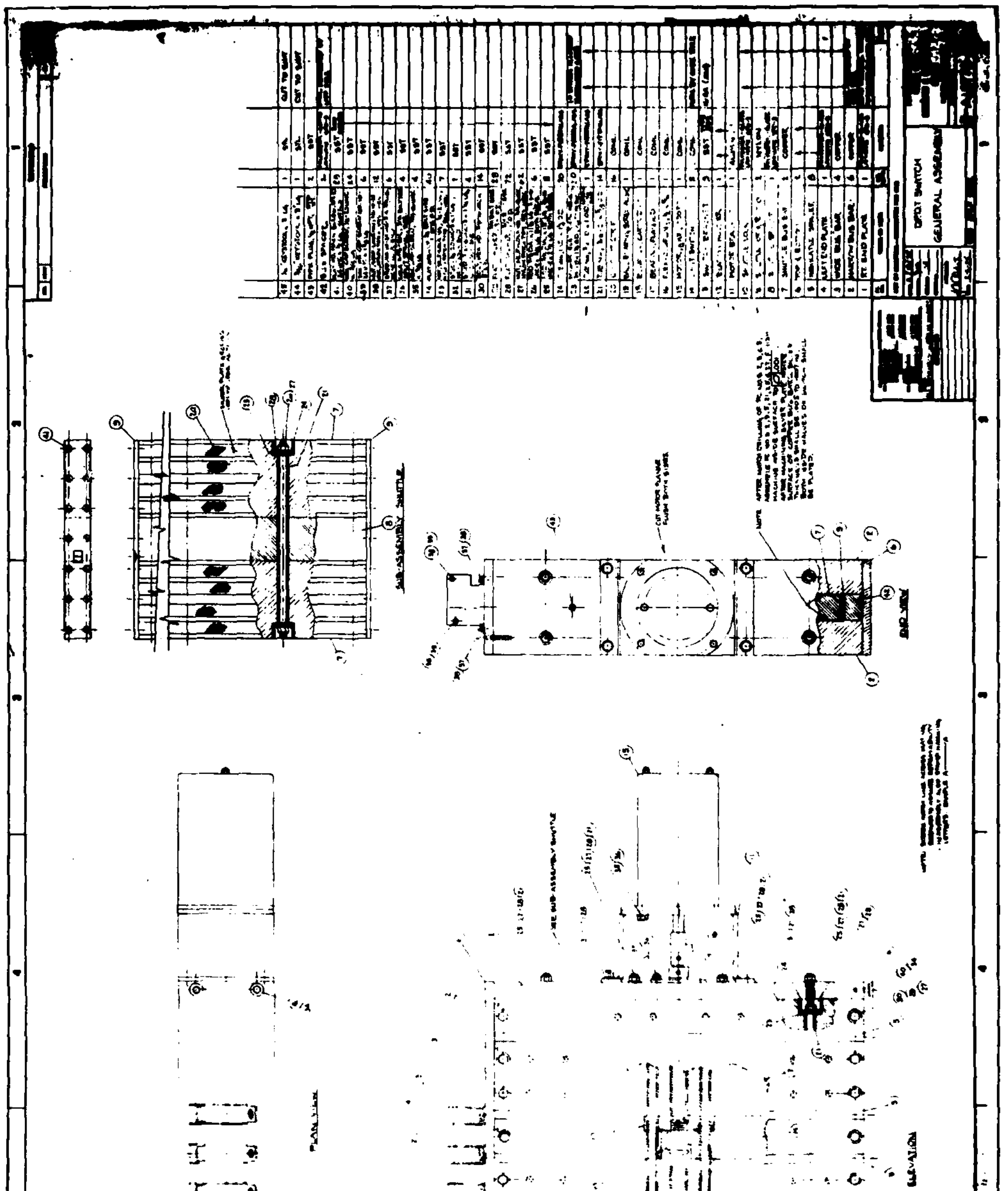


Figure 8 - DPDT Switch-General Assembly

SWITCH DETAILS

Figure 9 shows the details of the copper bus bars and insulating boards which make up the front and back of the switch and the insulating boards which make up the top, bottom, and sides of the switch. The copper bus bars (2 and 3) are made of OFHC certified copper. The insulating boards (1, 4, 5, and 6) are made of GP-03, Grade ETR-FR-C polyester glass, selected because its thermal expansion coefficient is close to that of copper and switch heating will cause low thermal stresses within the switch, particularly when the switch is fastened together with stainless steel hardware having approximately the same thermal expansion characteristics. In addition, the polyester glass is strong, is resistant to most oils, and is resistant to electrical arc tracking. The copper bus bars (2 and 3) are tapped for 2- x 4- x 4-in. terminal blocks which are fastened to the outside of the bus bars by 3/8-16 stainless steel screws. Electrical contact from the bus bars to the terminal blocks is made by soldering the terminal blocks to the bus bars using low-melting temperature solder. The 2- x 2-in. bus bars are tapped near the center so that current divides and flows from each outside edge toward the center, and the 2- x 4-in. bus bars are tapped at each end so that current flows nearly the entire length of the bus bar. The current density in each bus bar is thus made nearly the same.

Figure 10 shows the details of the shuttle parts (7, 8, 9, and 10) and the bus spacers (42). The top bus spacer has elongated holes for insertion of the position sensing switch plungers, and its length of 1.500 in. keeps the bus bars spaced the proper distance for clearance from the shuttle. The bottom bus spacer is identical to the top bus spacer except the elongated holes are omitted. The shuttle bus (7) has a width of 1.485 in., giving a 0.0075 in. clearance from the bus bars. The shuttle bus bars are grooved on each side for inserting the multilouvered contact strips in its surface. The shuttle spacers (8) hold the shuttle bus bars apart a distance of 2.50 in., and the shuttle lock (10) provides a mounting for the ball bearing screw assembly. Parts (8) and (10) are made of GPO-3, Grade ETR-FR-C polyester glass, and the shuttle bus bars are made of OFHC certified copper. The shuttle top and bottom (9) are used to provide a smooth sliding surface for the shuttle and are made of nylon. The shuttle top is notched to allow the plungers of each position sensing switch to actuate a switch when the shuttle reaches the forward, neutral, and reverse positions.

Figure 11 shows the details of the ball bearing drive screw (19), the drive motor mounting bracket (11), the position sensing switch mounting brackets (13), and the end bearing housing (12). The ball bearing drive screw is a stock item purchased in a 24-in. length, whose ends are modified to accommodate the shaft bearings and the motor drive mechanism.

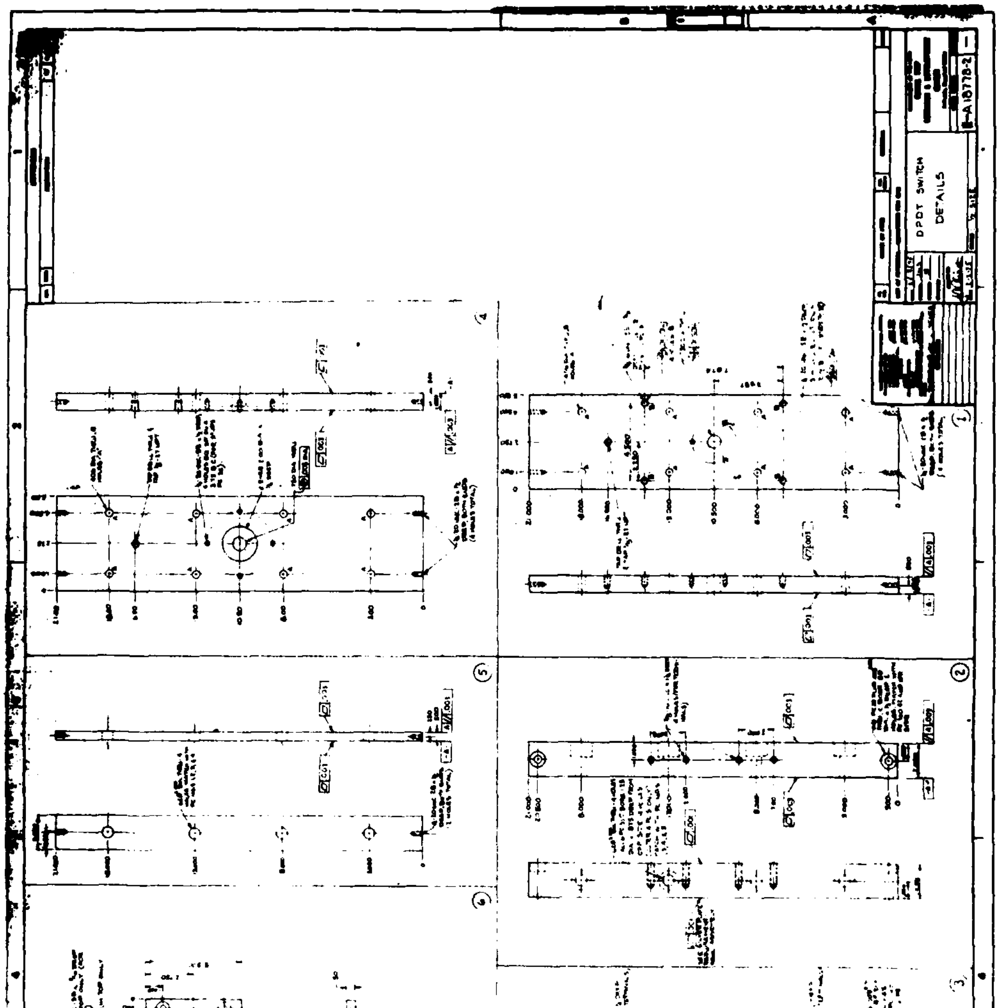


Figure 9 - DPDT Switch-Details

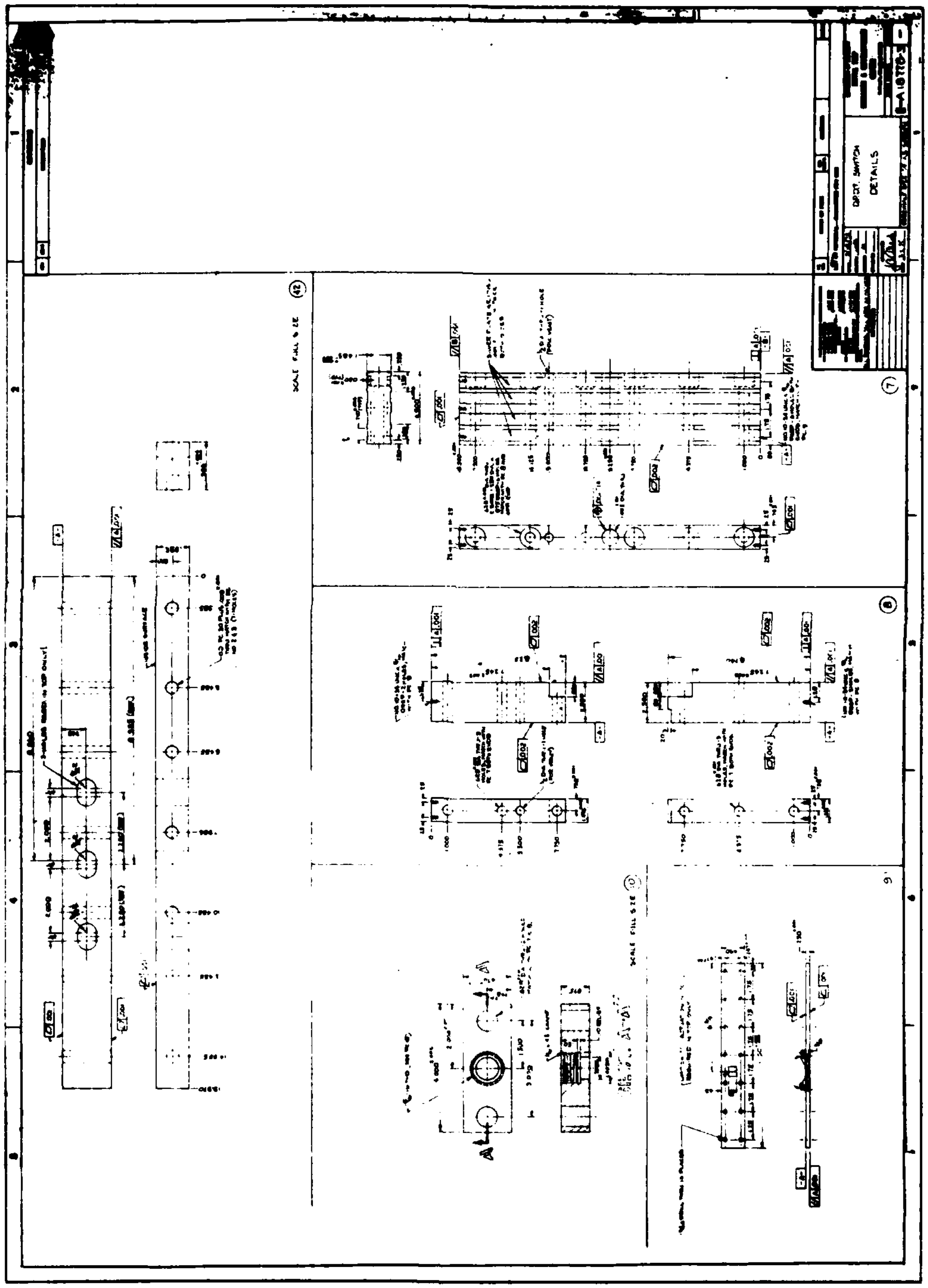


Figure 10 - DPDT Switch-Details

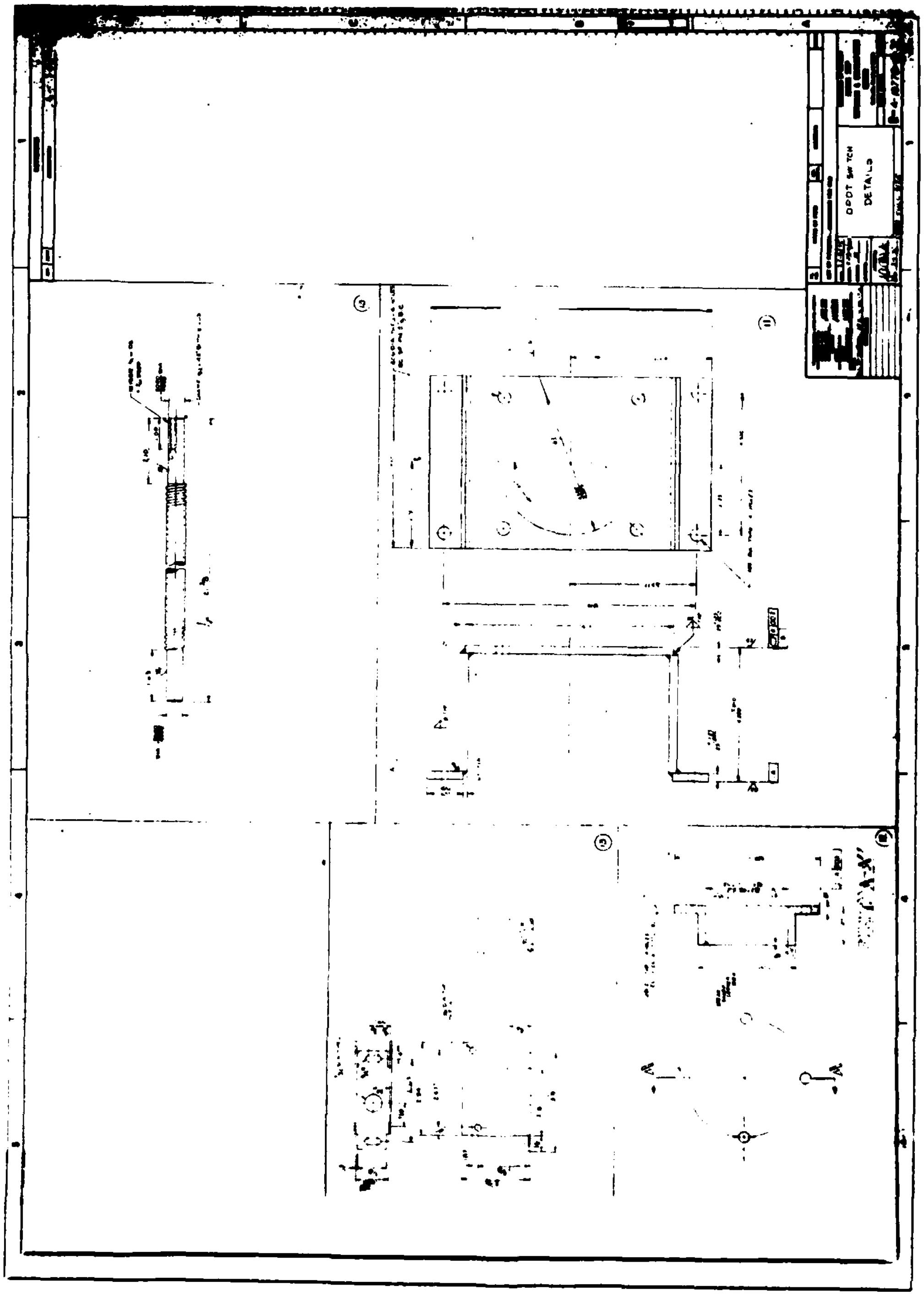


Figure 11 - DPDT Switch-Details

PRELIMINARY TEST RESULTS

Preliminary tests were performed on the switch to verify performance and to determine whether design modifications whould have to be made on this switch and on a SPST switch of similar design currently being constructed prior to use with the laboratory superconductive machinery. These tests were limited to 10,000-ampere current. The test setup is shown in Figure 12.

At the beginning of the tests, the switch was modified to improve its reliability. The modifications were also incorporated into the SPST switch at the time of its manufacture. The modifications were as follows:

1. The contact bands were coined into their grooves at intervals of 1/2 in. (1.27 cm). Originally they had been coined at intervals of 2-1/2 in. (6.35 cm), and that spacing was not sufficient to hold the bands flat in the grooves. As a result, there was a tendency for the strips to be pulled from the grooves when the shuttle was operated. After coining at 1.27-cm increments, no raising of the contact strips has been encountered.

2. A steel insert was made to fasten the ball nut to the shuttle. The threated portion of the plastic separator in the shuttle was not sufficiently strong to absorb the thrust from the shuttle and allowed the ball nut to pull loose. The steel insert prevented this difficulty.

3. A bearing housing was made to allow the bearing at the drive motor end of the switch to absorb thrust. The drive screw shaft was recessed to prevent axial movement of the bearing's shaft collar when the collar's set screw was tightened. These modifications were made to reduce stress on the drive shaft coupling.

4. Penzoil Type 303 grease was used as the contact lubricant. Originally, petroleum jelly was used as a lubricant, but it wiped off the contact surface readily and did not flow back into the area wiped clean by the contact bands. After a few switch operations, the contacts were operating dry. The grease is apparently able to flow back into the areas wiped clean by the contact bands and reestablish a lubricating film.

5. The sides of the switch were shimed 0.015 in. (0.0381 cm). Silver plating on the contact surfaces was thicker than specified, and shimming was necessary to bring the clearances and contact pressures back into specifica-tions. The shims will be removed as the contact surfaces wear to reestablish correct contact pressures.

The shuttle drive mechanism fully meets its design specifications. In the first operation of the shuttle, the "break away" torque was 40

1–POWER CABLES
2–BUS BAR TERMINAL
3–COOLANT LINE
4–DRIVE MOTOR
5–DPDT SWITCH

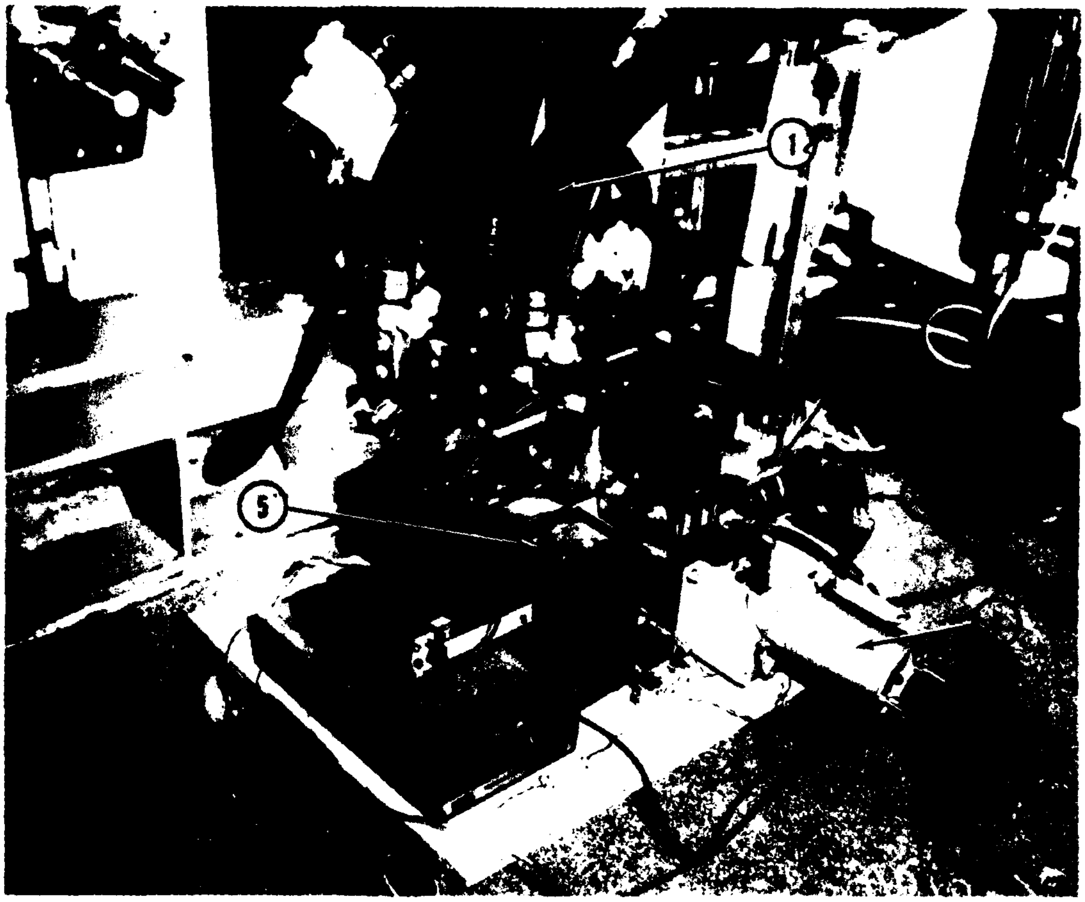


Figure 12 - DPDT Switch Preliminary Test Setup

lb-in. (4.5 N.m), and the running torque was 35 lb-in (3.94 N.m). After 70 complete cycles (forward-off-reverse-off-forward) the torques had dropped to 32 and 20 lb-in. (3.60 and 2.25 N.m), respectively, indicating that the newly machined contact surfaces had become polished. After 200 complete cycles, the torques remained at 32 and 20 lb-in. (3.60 and 2.25 N.m), indicating no further change in the character of the contact surfaces. Visual inspection confirmed that the surfaces had become polished. No wear of the contact strips was noted, but the flat contact surfaces had rounded grooves in the surface caused by the contact strips "wearing in". These grooves are a normal result of using these contact strips and did not cause any concern.

The drive motor is totally adequate for the switch. At its rating of 1/4 hp (186.5 watts) its continuous duty torque is 8 lb-in. (0.902 N.m). At locked rotor, its torque is 100 lb-in. (11.277 N.m). Because the motor operates intermittently, the loading it experiences while driving the shuttle is not detrimental to its life. The shuttle undergoes a complete cycle in 2.14 sec. At no load, the motor dynamically brakes in 1.5 revolutions. When loaded with the shuttle mechanism it stops within 1/10 of a shaft revolution or 0.02 in. (0.0508 cm) of advance on the drive screw. The dynamic braking under load is much better than had been anticipated. Operating time for a complete cycle is 2.14 sec. Operating time between adjacent switch positions is 0.53 sec.

Measured resistances at currents up to 50 amperes showed 2.4×10^{-6} ohms per contact half. Since contacts are on both sides of the switch, the resistance per contact is 1.2×10^{-6} ohms. Resistance measurements at a current of 10,000 amperes per contact half show an insertion resistance of 1.889×10^{-6} ohms at room temperature and 2.085×10^{-6} ohms at a shuttle temperature of 56.5°C. The lower resistance measured at high currents shows that the louvers in the contact bands deflect, due to magnetically induced forces, to press more tightly against the contact surfaces. This is a feature of these strips that was previously anticipated and is the feature that leads to their high overload capacities. The calculated resistance of the switch, is 2.196×10^{-6} ohms. The close agreement with the measured values indicates the predictability of the contact bands and the repeatability of the results obtained with them.

A sheet of tin plated copper contact interface material was placed between the switch and the bus bar terminals for investigation as a possible alternative to soldering the terminals to the switch. The interface resistance was 4.279×10^{-6} ohms on an 8-in.^{2} (51.616-cm^2) area and 2.439×10^{-6} ohms on a 16-in.^{2} (103.2-cm^2) area. Although these sheets are quite good for most electrical installations, they are not acceptable for the switch because their total resistance is three times the switch insertion resistance. We will proceed, as originally planned, to solder the terminals to the switch. The solder joint should have a resistance of approximately 2×10^{-8} ohms.

The resistance between the terminals and the bus bars measured 7.63 x 10^{-7} and 8.63 x 10^{-7} ohms at 10,000 amperes. The interface between the terminals and the bus bars is a multilam contact band rated 70 amperes per louver. In the final switch installation, these resistances should be approximately half of the values measured. In the test only half of the bus bar slot was used, and in the final installation the entire slot will be used.

Because of the high losses in the contact sheets between the terminals and the switch, the measured switch temperatures were considerably higher than expected. Even so, the temperature difference between the shuttle and cooling water in the terminals was 15.5°C. It should be noted that passing 10,000 amperes into only one side of the switch is roughly equivalent to passing 20,000 amperes through the switch for the purpose of resistance and temperature measurements.

These preliminary test results have shown that the switch fully meets the design specifications, and in several instances has exceeded expectations.

CURRENT STATUS AND FUTURE PLANS

The DPDT switch has been constructed, and preliminary testing has been completed. It has been installed in a switchgear console along with an intermittent duty rheostat, a shunt switch, and a controller. The console will be tested along with a 400-hp superconductive propulsion system being developed at DTNSRDC. Reports on the DPDT switch tests in conjunction with these other elements will be released at the conclusion of those tests.

REFERENCES

1. Steen, D. B., "Switchgear Investigations for a 400 Horsepower Superconductive Propulsion System," DTNSRDC Report 4436 (July 1975).

2. Hugin, Peter E., "Guide to Multilam Technology," Multilam Corp. Memorandum (July 1973).

3. "Guide Manual of Cooling Methods for Electronic Equipment," NAVSHIPS 900, 193 (Mar 1955), pp. 22-26.

INITIAL DISTRIBUTION

Copies		
8	NAVSEA 1 SEA 05D 3 SEA 05R 1 SEA 5422 1 SEA 5432 2 SEA 99612	
12	DTIC	
1	AiResearch Manufacturing Co. 2525 West 190th St. Torrance, CA 90509 Attn: Mr. M. Calderon	
1	General Electric Co. Corporate Research and Development P. O. Box 43 Schenectady, NY 12301 Attn: Mr. R. A. Marshall	
1	Westinghouse Electric Co. Research and Development Center 1310 Beulah Rd. Pittsburgh, PA 15235 Attn: Dr. D. L. Green	

CENTER DISTRIBUTION

Copies	Code	Name
1	271	
1	2711	
15	2712	D. Steen
1	522.1	Library
2	5231	Office

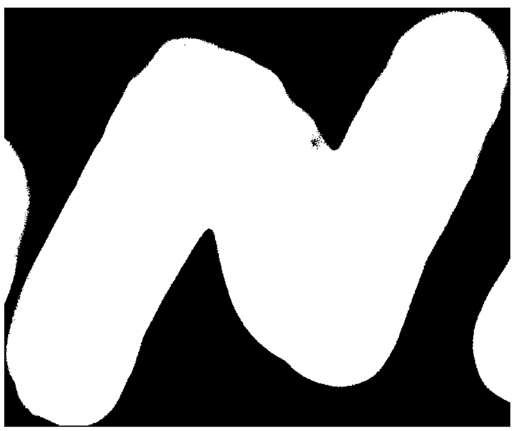
DTNSRDC ISSUES THREE TYPES OF REPORTS

1. DTNSRDC REPORTS, A FORMAL SERIES, CONTAIN INFORMATION OF PERMANENT TECHNICAL VALUE. THEY CARRY A CONSECUTIVE NUMERICAL IDENTIFICATION REGARDLESS OF THEIR CLASSIFICATION OR THE ORIGINATING DEPARTMENT.

2. DEPARTMENTAL REPORTS, A SEMIFORMAL SERIES, CONTAIN INFORMATION OF A PRELIMINARY, TEMPORARY, OR PROPRIETARY NATURE OR OF LIMITED INTEREST OR SIGNIFICANCE. THEY CARRY A DEPARTMENTAL ALPHANUMERICAL IDENTIFICATION.

3. TECHNICAL MEMORANDA, AN INFORMAL SERIES, CONTAIN TECHNICAL DOCUMENTATION OF LIMITED USE AND INTEREST. THEY ARE PRIMARILY WORKING PAPERS INTENDED FOR INTERNAL USE. THEY CARRY AN IDENTIFYING NUMBER WHICH INDICATES THEIR TYPE AND THE NUMERICAL CODE OF THE ORIGINATING DEPARTMENT. ANY DISTRIBUTION OUTSIDE DTNSRDC MUST BE APPROVED BY THE HEAD OF THE ORIGINATING DEPARTMENT ON A CASE-BY-CASE BASIS.

END
DATE
FILMED
8 80
DTIC



AD-A086 289 DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 21/3
DEVELOPMENT OF A 30,000-AMPERE REVERSING CONTACTOR.(U)
MAY 80 D B STEEN
UNCLASSIFIED DTNSRDC/PAS-79/40 NL

2 OF 2

END
DATE FILMED
4-81
DTIC

DA
086

SUPPLEMENTARY

INFORMATION

AD-A086289

DAVID W. TAYLOR NAVAL SHIP RESEARCH
AND DEVELOPMENT CENTER
HEADQUARTERS
BETHESDA, MARYLAND 20084

ANNAPOLIS LABORATORY
ANNAPOLIS, MD 21402
CARDEROCK LABORATORY
BETHESDA, MD 20084

IN REPLY REFER TO:
2712:DBS
9480

06 AUG 1980

From: Commander, David W. Taylor Naval Ship R&D Center
To: Distribution List

Subj: DTNSRDC Report PAS-79-40; Pen and ink changes to

1. The subject report has been revised. Please make the following pen and ink changes to your copies.

a. On page 5, second paragraph, change "7.74 and 10.96 A/m^2" to 774 and 1096 A/cm^2.

b. On page 12, the upper limit of integration for the 2x2 in contact is 10.5 instead of the 11.5 shown. Change the limit of integration from "11.5" to 10.5, the power loss in the last column from "88.08" to 67.04, and the total losses from "1977" and "2697" to 1896 and 2616 respectively.

c. On page 16, the abscissa of the graph should be labeled INCH POUNDS.

d. On page 17, the electrical characteristics are 1896, 2616, 2.106×10^{-6} and 2.907×10^{-6} instead of the numbers shown.

e. On page 26, third paragraph change "2.196×10^{-6}" to 2.106×10^{-6}.

W. C. DIETZ
By direction

DISTRIBUTION LIST
NAVSEA 05D
NAVSEA 05R
NAVSEA 5422
NAVSEA 5432
NAVSEA 99612
DTIC
AiResearch Manufacturing Co. (M. Calderon)
General Electric Co. (R. A. Marshall)
Westinghouse Electric Co. (D. L. Green)

ANNAPOLIS LABORATORY
ANNAPOLIS, MD 21402
CARDEROCK LABORATORY
BETHESDA, MD 20084
IN REPLY REFER TO:

2712:DBS
9480

6 AUG 1980

wing pen and

2" to

in contact
integration
from "88.08"
o 1896 and

INCH POUNDS.

16,
own.

106 x 10^{-6}.

DIETZ
ction

END

DATE
FILMED

4-8

DTIC